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THE EFFECT OF CLEARCUTTING AND SOIL DISTURBANCE ON TEMPERATURES NEAR THE SOIL SURFACE IN SOUTHEAST ALASKA

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CONTENTS

Page

Introduction 1

Description of the study area 2

- Climate 2
- Vegetation. 3
- Soils 3
- Seedbed conditions 4

Methods and instrumentation 4

- 1952 4
- 1955 5

Results 5

- Effect of clearcutting on air and soil temperatures 5
- Air and soil temperature in the environment of seedlings. 12
- Effect of seedbed on germination. 17

Summary and conclusions 20

Literature cited 21

THE EFFECT OF CLEARCUTTING AND SOIL DISTURBANCE ON TEMPERATURES NEAR THE SOIL SURFACE IN SOUTHEAST ALASKA

by
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INTRODUCTION

Air and soil temperatures near the soil surface are believed to exert considerable influence on the germination, establishment and early growth of tree seedlings in Southeast Alaska. The northern latitude and maritime climate of this region result in mean growing season temperatures which are not greatly above that considered minimum for plant growth.

Arresting of soil biological activity and plant growth is generally considered to occur at about 40° F. Weaver and Clements (1929) noted that the plant zeros most used have been 43° and 40° F. Lyon, Buckman, and Brady (1952) state that soil chemical and biological activity will not continue with adequate intensity unless certain temperatures are maintained. They refer, as an example, to nitrification which does not begin until the soil reaches a temperature of about 40° F., the most favorable limits being 80° to 90°. Waksman and Gerretsen (1931) working with oat straw found that decomposition was negligible at temperatures of 7° C. (44.5° F.). Similarly, Bartholomew and Norman (1946) observed earlier initiation of decomposition and a more rapid rate of carbon dioxide evolution at higher temperatures during the course of a 12-day experiment with white pine (Pinus strobus L.) needles; at 12° C. (53.6° F.) decomposition, as measured by carbon dioxide evolution, was very limited and much delayed.

The period of germination of white pine (Adams, 1934) and tamarack (Larix laricina (Du Roi) K. Koch) (Duncan, 1954) has been observed to be appreciably extended at lower soil temperatures. Tamm (1950), referring to studies by Mork in Norway and Tiren in Sweden, reports that spruce and pine seed did not seem to germinate when the surface soil temperature was below 7° C. (44.6° F.), even when moisture conditions were favorable. Root growth of temperate tree species has been repeatedly observed to progress very slowly or cease at soil temperatures of 40° to 45° F. (Kienholtz, 1934; Batjer et al, 1939; Kaufman, 1945). Andersen (1955) points out that low temperatures in Southeast Alaska during the growing season may be a limiting factor for tree growth as shown by the preponerance of high site classes on south slopes and the decrease of average site index in the northern portion of the region. Apparently temperatures during the growing season largely determine the limits of the range of western redcedar (Thuja plicata D. Donn) in Southeast Alaska (Andersen, 1953).

Extremes in temperature, particularly near the soil surface in exposed areas, frequently have an adverse effect on germination and survival of seedlings. Mortality of coniferous seedlings caused by heat lesions has been observed when soil surface temperatures reached 110° to 130° F. (Baker, 1929; Isaac, 1938). Vaartaja (1954) referring to an unpublished test, states that high surface temperatures encountered in Finland were found, in extreme cases, to decrease the germination percentage of seed of Scotch pine (Pinus sylvestris L.). Isaac (1938) recorded seedling mortality of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) when night air temperatures dropped to 27° and 26° F. and surface-soil temperatures in exposed spots went as low as 23° F.

It is universally recognized in regions such as Southeast Alaska where summer temperatures are near minimum for plant growth, that changes in temperature, even of a small magnitude, may strongly influence biological response. Clearcutting, the method of harvest employed in this region, will undoubtedly have a pronounced effect on air and soil temperatures near the soil surface on cutover areas.

This paper includes a study of air and soil temperature differences occurring as a result of clearcutting. Attention has been given to extremes in temperature near the soil surface in clearcut areas in relation to seedling germination and survival.

DESCRIPTION OF THE STUDY AREA

Field work was conducted in the vicinity of Hollis, Alaska, on Prince of Wales Island, located at latitude 55° 28' N. longitude 132° 41' W. This area is typical of the coastal islands of the region. The topography is mountainous, slopes are essentially steep and are dissected by many drainages. Numerous inland waterways exist. The shore lines are deeply indented with frequent long, narrow inlets.

Climate

Andersen (1955) presents a complete summary of climate in relation to tree growth in Southeast Alaska. The climate of the study area is slightly milder than that encountered on the mainland and northern coastal islands. A climatological station, located on the beach at sea level, was maintained at Hollis during the period of the study.

A relatively cool, moist, equable climate prevails throughout the growing season (table 1). Maximum air temperatures greater than 80° F. are infrequent, and daily variations are seldom extreme. A pronounced dry period does not occur. Precipitation, however, is generally less during the growing season than at other times of the year. Occasionally, periods exceeding a week in length without rain occur. During the 1952 summer season there were three such rainless periods of 8, 9, and 13 days duration; rainless periods of 8 and 12 days occurred in 1954. In 1953 and 1955, periods of no rainfall were of less than one week duration.

Table 1.--Air temperature at 3 feet and rainfall data during the growing season, Hollis, Alaska

Year	Month	TEMPERATURE, °F Max.	Min.	Mean	Absolute Max.	Absolute Min.	Rainfall inches
1952	May	--	--	--	--	--	--
	June	61	44	52	72	33	3.36
	July	69	50	59	85	43	3.74
	Aug.	68	51	60	81	42	3.98
	Sept.	58	48	53	66	40	12.91
1953	May 1/	59	41	50	78	32	2.26
	June	65	46	55	75	38	1.77
	July	67	50	58	84	40	2.21
	Aug.	65	50	58	81	44	5.49
	Sept. 2/	60	46	53	68	36	10.44
1954	May	56	39	47	70	29	2.79
	June	61	45	53	70	37	2.86
	July	62	48	55	74	39	2.95
	Aug.	70	50	60	81	42	0.42
	Sept.	61	45	53	72	36	5.48
1955	May 3/	54	36	45	60	31	6.16
	June	60	42	51	79	32	3.21
	July	67	51	59	83	39	0.91
	Aug.	60	50	55	71	43	7.14
	Sept.	58	46	52	68	34	8.28

1/ Record from 5/9 through 5/31.
2/ Temperature records missing for 11 days.
3/ Temperature records missing 5/1 through 5/7.

Vegetation

In both the timbered and clearcut study areas the predominant tree species was western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in association with Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and western redcedar. These were overmature, old-growth stands. Moderate to dense understories of brush, consisting principally of blueberry (*Vaccinium ovalifolium* Smith, *V. parvifolium*, Smith, *V. uliginosum* L.) and menziesia (*Menziesia ferruginea*, Smith) predominated over most of the area.

Soils

On all of the sites where temperature observations were made, the soils were well, or moderately well-drained. Profile cuts showed weakly developed podzols of the following description:

Horizons	Descriptions
A_0	Greasy mor (Heiberg and Chandler, 1941); 5-8 inches thick.
A_2	Light gray; 0-2 inches thick; gravelly sandy loam; single grain; loose.
B_h	Very dark brown; 0-1 inches thick; gravelly sandy loam; weak medium subangular blocky; very friable.
B_2	Red or yellow brown; 4-12 inches thick; gravelly sandy loam; weak medium subangular blocky; very friable.
B_3	Yellow brown, 0-8 inches thick; gravelly sandy loam; massive; very friable.
C or D	Unweathered till or bedrock.

Prior to logging disturbance these soils were covered with a dense growth of mosses, predominately *Hylocomium* and *Eurhynchium* spp. The F horizon of the organic layer was from one to three inches below the surface of the moss.

Seedbed conditions

Clearcutting causes soil disturbance of varying degrees which creates a variety of seedbed conditions. From the results of clearcutting observed in Southeast Alaska it appears that soil disturbance is beneficial as it mixes the organic and mineral soil horizons. The most undesirable seedbed condition, other than dense brush or heavy slash, appears to be an undisturbed, moss-covered soil (Godman, 1953). Particular attention has been given to the mixed soil and undisturbed, moss-covered soil in this study.

METHODS AND INSTRUMENTATION

Field work was begun during the 1952 field season and was continued and concluded during the 1955 season.

1952

The primary objective at this time was to ascertain the effect of clearcutting on air and soil temperatures. Large-scale logging operations had not begun. The only clearcut area available was about 2.5 acres in size, bordering the beach on a small island. Two stations were established; one in the open, and one in the adjacent timber. The open station was about 400 feet from the beach at an elevation of 50 feet above sea level. The timbered station was about 800 feet from the beach, at an elevation of 200 feet, and 300 feet from the edge of the cutting.

Bristol dual-pen thermographs were installed at each station for continuous recording of air temperature at 3 feet and soil temperature at 3 inches. Numerous other observations of an exploratory nature were made under varying soil and cover conditions.

1955

In 1955, stations were set up on a large clearcut area recently logged for pulptimber. To observe the effect of clearcutting, two continuous recording stations were established using the same instruments as in 1952. They were located on a moderately steep slope, exposed to the southwest, at approximately 500 feet above sea level and 400 feet above the valley bottom. The timbered station was in a residual seed strip of timber which extended from the uphill border of the cutting to the valley bottom (figs. 1, 2, and 3). Air and soil temperatures were measured at 3 feet and 3 inches respectively, as in 1952. Soil pits were dug at the open and timbered stations to allow weekly measurements of soil temperatures at depths of 12, 18, and 24 inches.

Four 1/4-milacre plots were established below the open recording station at about 250 feet elevation to record the range of temperatures which germinating and established seedlings encounter. Two of these were on mixed soils where the organic and upper mineral horizons were incorporated, and two on an undisturbed soil with a moss-covered surface. Maximum and minimum temperatures were taken on one of the mixed and one of the undisturbed plots. Weather Bureau type maximum-minimum thermometers were set at 1-inch above the soil surface, at the soil surface, and 1-inch below the surface. The surface of the F layer represented the soil surface on the undisturbed plot. The surface of the moss layer represented 1-inch above the soil surface (figs. 4, 5, and 6).

The four 1/4-milacre plots in the open, plus two others located near the timbered thermograph station, were seeded with 200 seeds each of western hemlock, Sitka spruce, and western redcedar. Germination and mortality were noted on all plots at weekly intervals.

RESULTS

Effect of Clearcutting on Air and Soil Temperatures

Temperatures in the open were consistently higher than those in the timber during the summer months (table 2 and fig. 7). The only exception was minimum air temperature which either displayed little difference, or tended to be slightly higher in the timber.

Differences were most pronounced during early season warming and during periods of highest maxima since the open environment responded more rapidly to change; gain and loss of heat in the timber was comparatively slow. The greatest differences in temperature between the open and timber were in soil maxima. Next in order of magnitude were air maxima, and soil minima. Differences in air minima were negligible. As fall approached, overcast skies and increasing precipitation tended to minimize extremes and reduce the temperature differences between the open and timbered areas.

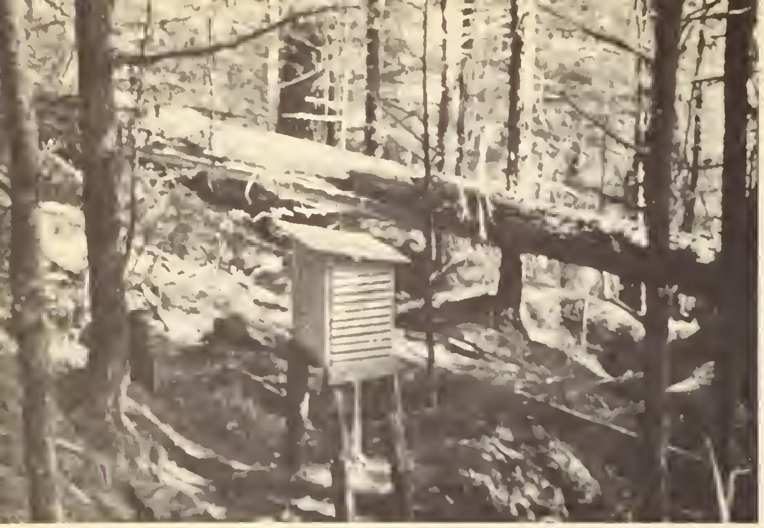

Figure 1.--Instrument shelter at 1955 timbered station.

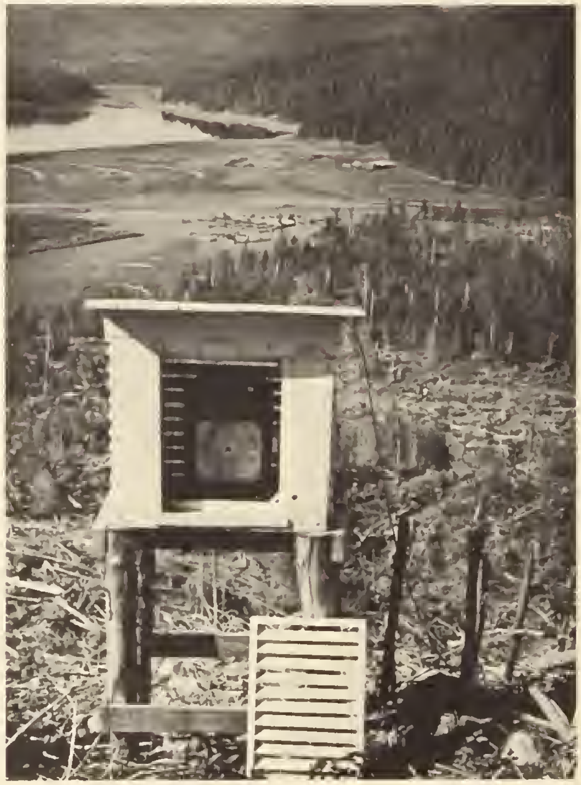

Figure 2.--Instrument shelter at 1955 open station.

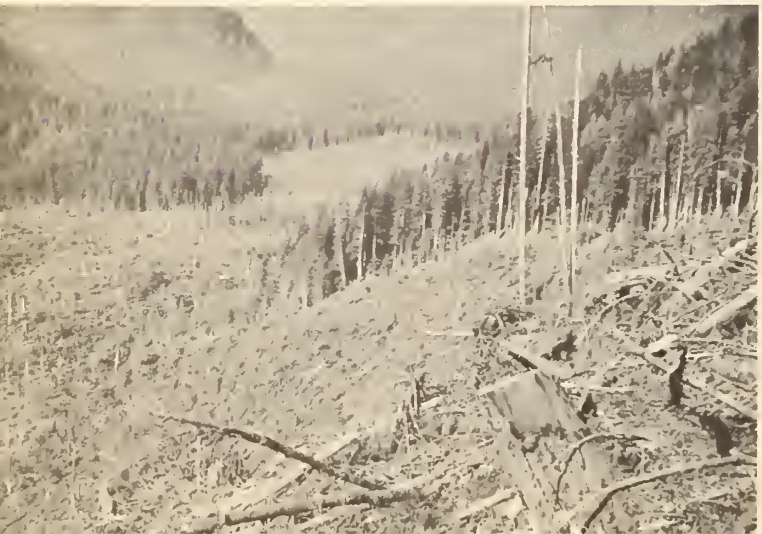

Figure 3.--Part of the Maybeso clearcut. The residual strip of timber in which the 1955 timbered station was located extends from the center to upper right corner of the photograph.

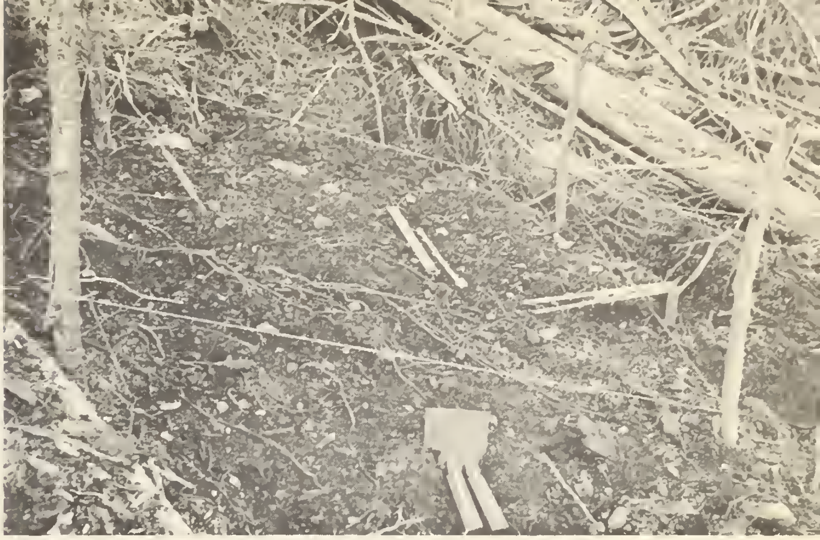

Figure 4.--Mixed soil plot showing max.-min. thermometer pairs at 1-inch above the surface, at the surface, and 1-inch below the surface.

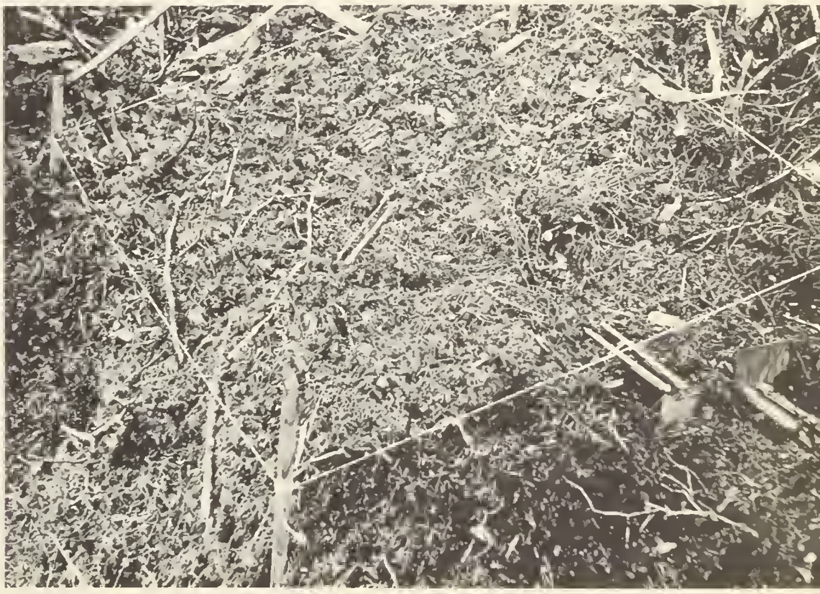

Figure 5.--Undisturbed moss-covered plot.

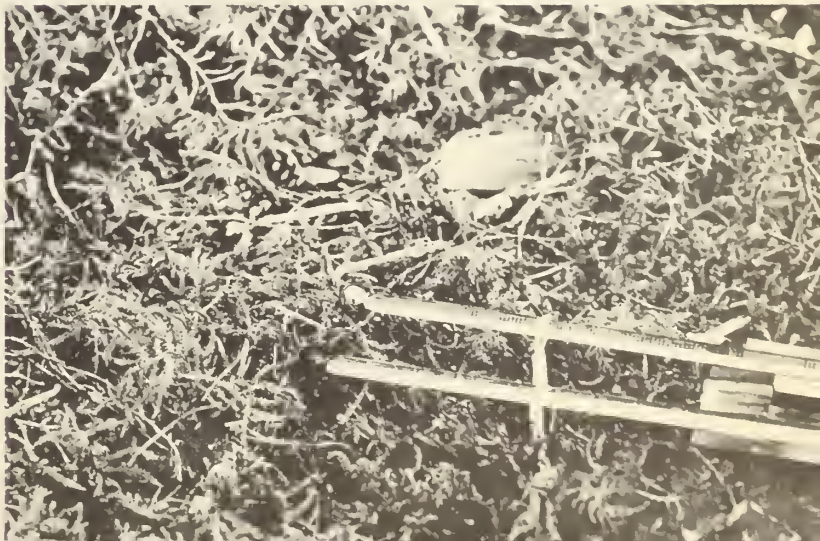

Figure 6.--Close-up view of moss covering the undisturbed surface, and the max.-min. thermometer pair at 1-inch above the surface.

Table 2.--Average maximum, minimum, and mean temperature differences between the open and timber by six-day periods. Air -3 feet and soil -3 inches.

(Degrees F.)

Period	1952						1955					
	Max.		Min.		Mean		Max.		Min.		Mean	
	Air	Soil	Air	Soil	Air	Soil	Air	Soil	Air	Soil	Air	Soil
6/1-6/6	2.3	8.4	0.8	7.0	1.6	7.7	5.4	8.6	-0.8	2.0	2.3	5.3
6/7-6/12	3.4	10.1	-0.3[1]	6.5	1.6	8.3	5.8	9.2	-1.5	1.5	2.2	5.4
6/13-6/18	3.6	8.8	1.1	6.8	2.4	7.8	4.0	8.4	-0.5	1.6	1.8	5.0
6/19-6/24	3.2	8.4	0.6	5.9	1.9	7.2	8.0	13.5	-2.0	2.3	3.0	7.9
6/25-6/30	3.7	8.5	0.5	5.8	2.1	7.2	4.1	8.2	-1.5	2.8	1.3	5.5
7/1-7/6	2.6	7.0	0.9	5.9	1.8	6.4	6.8	11.8	-4.7	2.6	1.0	7.2
7/7-7/12	2.3	7.0	-1.1	4.0	0.6	5.5	4.9	9.4	-0.2	4.3	2.4	6.8
7/13-7/18	4.3	8.6	-1.0	4.3	1.6	6.4	5.5	11.4	-1.4	2.3	2.0	6.8
7/19-7/24	4.3	9.2	0.6	5.8	2.4	7.5	4.5	8.9	-0.5	2.8	2.0	5.8
7/25-7/30	4.0	10.4	0.4	5.5	2.2	8.0	4.8	9.5	-1.0	3.1	1.9	6.3
7/31-8/5	4.2	9.5	0.3	5.5	2.2	7.5	3.2	7.5	-1.2	3.4	1.0	5.4
8/6-8/11	5.4	10.2	-0.3	5.0	2.6	7.6	2.0	5.1	0.5	2.2	1.2	3.6
8/12-8/17	3.3	8.0	-0.1	5.3	1.6	6.6	2.7	5.7	0.3	1.6	1.5	3.6
8/18-8/23	4.4	6.2	1.2	4.3	2.8	5.2	4.2	9.0	-0.8	1.5	1.7	5.2
8/24-8/29	3.8	6.0	0.0	2.9	1.9	4.4	6.6	10.0	-0.7	1.9	3.0	6.0
8/30-9/4	2.8	5.5	0.1	2.9	1.4	4.2	2.8	5.2	0.1	1.5	1.4	3.4
9/5-9/10	2.1	3.1	0.7	1.9	1.4	2.5	7.9	12.2	-1.8	0.3	3.0	6.0
9/11-9/16	1.9	3.9	0.8	2.0	1.4	3.0	3.0	3.3	0.1	1.0	1.6	2.2
9/17-9/22	1.5	3.0	0.3	1.5	0.9	2.2	--	8.2	--	-1.8	--	3.2
9/23-9/28	1.5	2.3	0.6	1.1	1.1	1.7	--	4.6	--	1.3	--	3.0
Average[2]	3.4	7.7	0.3	4.8	1.9	6.3	4.8	8.7	-1.0	2.2	1.9	5.4

[1] Minus figures indicate that temperatures were higher in the timber than in the open.

[2] Excluding period from 9/17 through 9/28. Lack of 1955 air temperature data during this period prevents an accurate comparison with other temperature values.

Temperature differences between the open and timbered areas were relatively large and uniform. As shown in table 2, 6-day mean differences ranged from a low of 0.6° to a high of 3.0° F. at air-3 feet, and 1.7° to 8.3° at soil-3 inches. The largest recorded daily difference in maximum temperature was 12° for air and 17° for soil, both of which occurred on June 22, 1955, when air and soil in the open reached 84° and 69° respectively.

Absolute maximum and minimum temperatures for the period of record are shown in table 3 for the various thermograph stations, and in table 4 for the Hollis weather station. Air temperatures greater than 80° at the open stations occurred on only 8 days, and between 70° and 80° on 27 days during the entire period of record. In the timber, no air temperatures as high as 80° were recorded; maxima higher than 70° occurred on only 17 days. Rarely did soil temperatures reach 70° in the open or 60° in the woods.

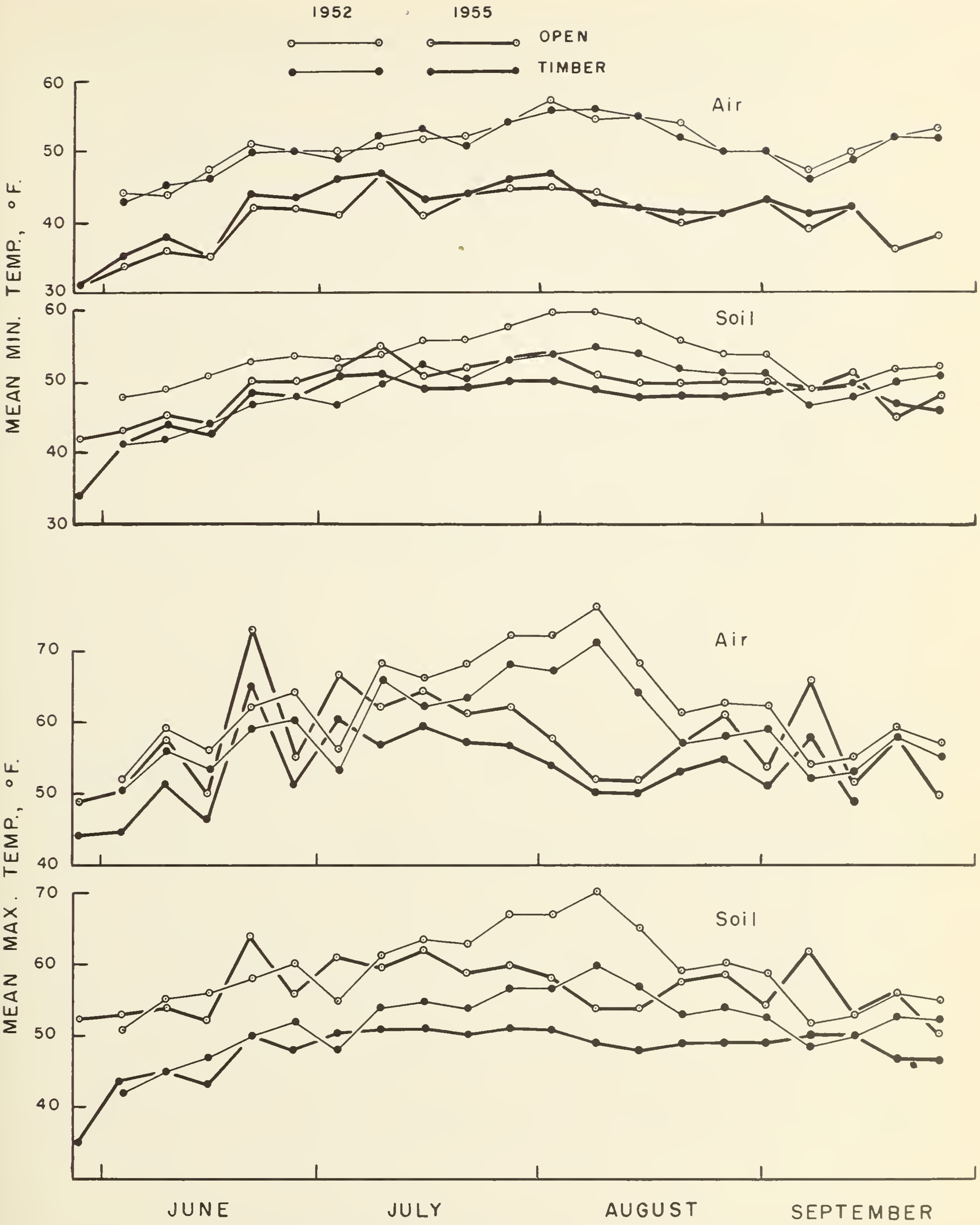

Figure 7.--Summer march of mean maximum and minimum temperatures by six-day periods at air-3 feet and soil-3 inches. Open and timbered stations, 1952 and 1955.

Table 3.--Absolute summer (June through September) maximum and minimum temperatures at air-3 feet and soil-3 inches recorded at the open and timbered thermograph stations

Year	Location	Extreme Temperature, °F					
		Max.		Min.		Range	
		Air	Soil	Air	Soil	Air	Soil
1952	Open	83	72	37	45	46	27
	Timber	78	62	38	40	40	22
1955	Open	84	70	33	39	51	31
	Timber	74	53	36	40	38	13

Table 4.--Absolute summer (June through September) maximum and minimum temperatures (air-3 feet) measured at the Hollis weather station

Year	Extreme Temperature, °F		
	Max.	Min.	Range
1952	85	33	52
1953	84	38	46
1954	81	36	45
1955	83	32	51

The lowest minima for both air and soil occurred early in the summer season. Late summer minima were modified by the prevalence of overcast skies and heat stored in the soil. No freezing temperatures occurred at either station although they closely approached freezing during late May and early June. Minimum temperatures in the thirties are common during some years through the first half of June. Damage to early growth is possible during these months, particularly where air drainage is poor.

The seasonal temperature march in the deeper soil layers[1/] is shown in fig. 8. The 24-inch depth at the timbered station is of particular interest because of the low temperatures, very slow rate of warming, and small amount of weekly fluctuation. Considering these low temperature values, it is not surprising that root penetration is very limited in this zone and that seldom is soil solum development very noticeable at or beyond this depth. The influence of clearcutting is still apparent and consistent at the 24-inch depth and, again, is most pronounced during the warmest part of the season. Maximum differences at the 12-, 18-, and 24-inch depths were 9°, 7°, and 5°, respectively.

[1/] Measurements made with ordinary mercurial thermometers at weekly intervals.

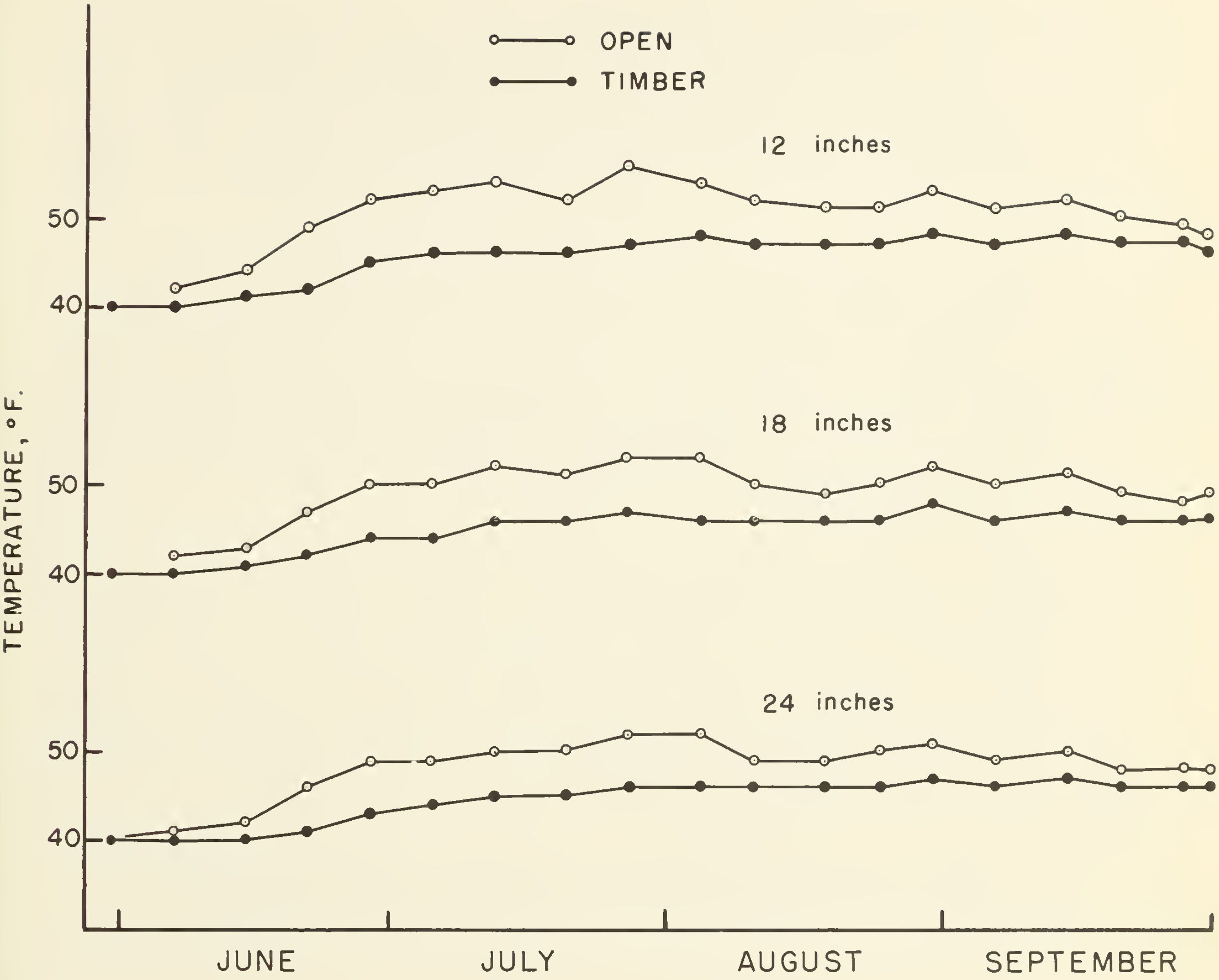

Figure 8.--Summer march of temperature at soil depths of 12, 18, and 24 inches. From temperature observations taken at about one-week intervals at the 1955 open and timbered stations.

Dissipation of incoming and outgoing heat in the soil is principally responsible for temperature differences between undisturbed moss-covered and mixed-soil seedbeds. Heat is more easily conducted through the comparatively tightly-packed mixed soil[2] in which mineral matter is incorporated than through the loosely-packed organic soil with the moss-covered surface.[3] Heat due to incoming radiation is accumulated at the surface of the undisturbed soil. Within the organic layer heat gain and loss is lessened.

The magnitude of temperature differences between the undisturbed and mixed soil seedbeds is shown by the seasonal march of 6-day means in figs. 9a and b. The greatest extremes occurred at the soil surface. The largest range in extremes, with the exception of soil at 1-inch, occurred on the undisturbed plot. At soil-1-inch, lower maxima and higher minima prevailed on the undisturbed plot. Differences in maxima were much more pronounced than in minima. Periods of clear weather, conducive to maximum gain and loss of heat by radiation, resulted in the greatest extremes and most diversity between seedbeds.

Table 5 shows the absolute summer maxima and minima which occurred during the 1955 period of observation. Temperatures higher than 100° F. were fairly common at the surface of the undisturbed soil, but occurred only on three days on the mixed soil surface. Maxima of 120° and higher occurred at the undisturbed soil surface on eight days, and on four days surface soil temperatures reached 123°. Temperatures of this magnitude were found to cause injury to Douglas-fir seedlings in the Pacific Northwest when repeated for several days (Isaac, 1938).

Table 5.--Absolute maximum and minimum temperatures during the summer season (June through September, 1955) at near-soil-surface levels

Seedbed	Observation level	Extreme Temperature, °F Max.	Min.	Range
Mixed	Air-1-inch	100	27	74
	Surface	114	26	88
	Soil-1-inch	112	38	74
Undisturbed	Air-1-inch	121	27	94
	Surface	130	27	103
	Soil-1-inch	76	38	38

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[2] Hereafter referred to as "mixed" soil, plot, or seedbed.
[3] Hereafter referred to as "undisturbed" soil, plot, or seedbed.

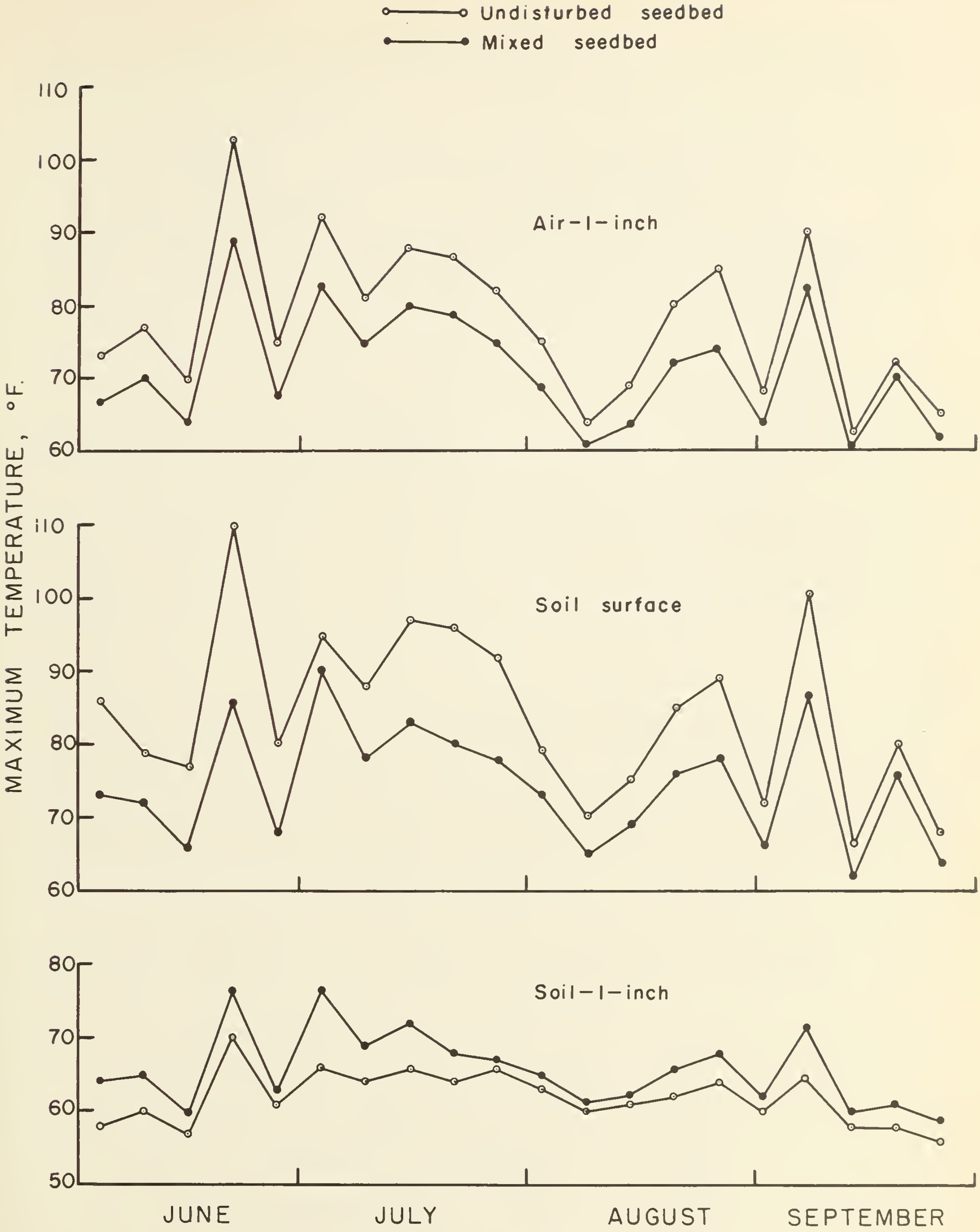

Figure 9a.--March of mean maximum temperature by six-day periods for near-soil-surface levels. Mixed and undisturbed seedbeds in the open.

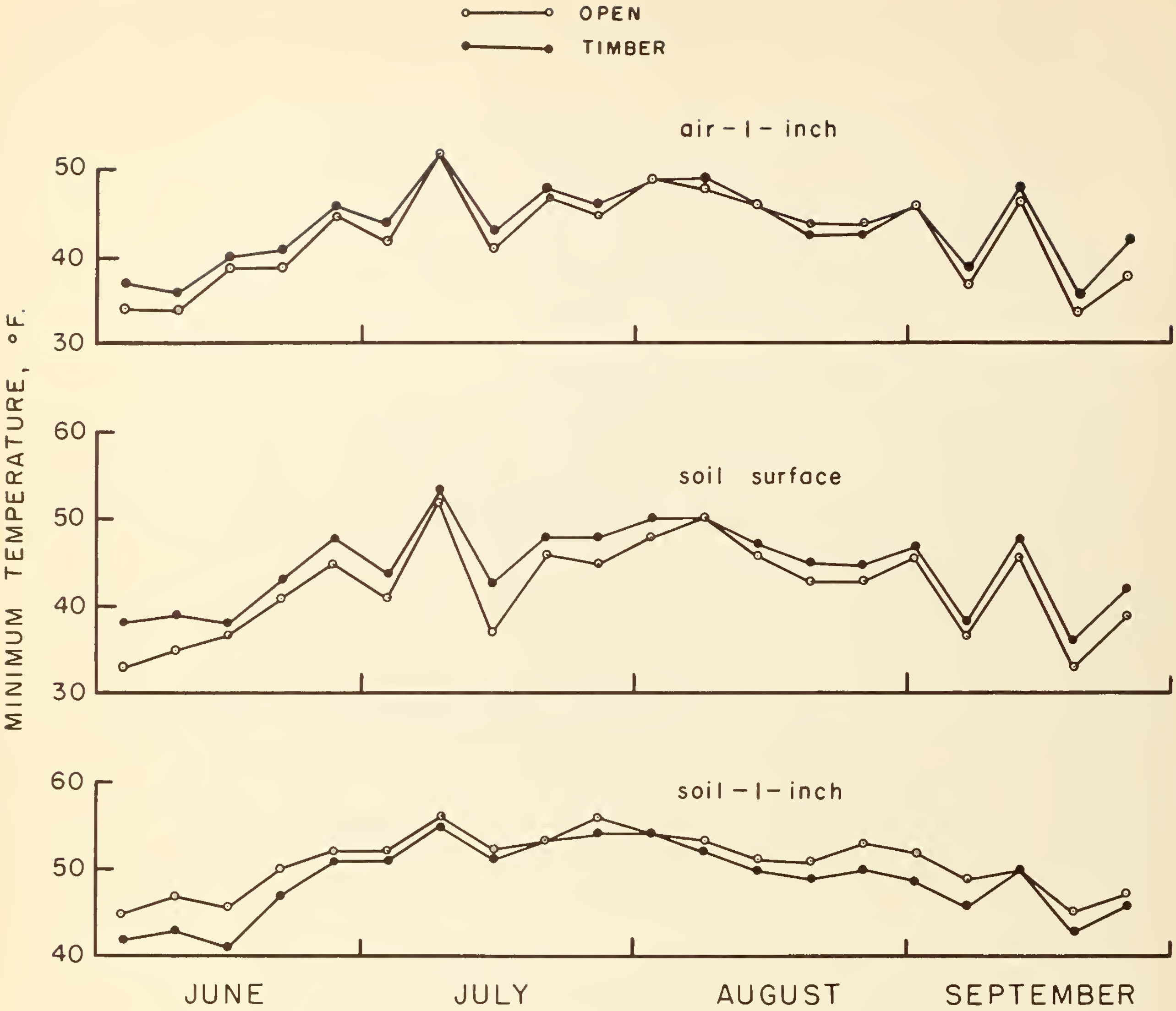

Figure 9b.--March of mean minimum temperature by six-day periods for near-soil-surface levels. Mixed and undisturbed seedbeds in the open.

At the undisturbed soil surface, minimas of 32° and less were observed five times in June, twice in July, and three times in September, of which three in June and two in September were below 30°. At the mixed soil surface, temperatures dropped to the freezing threshhold of 32° only twice, both times during the first half of June. The greatest diurnal range noted was 94° when surface temperature on the undisturbed soil rose from a low of 36° to a high of 130°.

An analysis was made to determine the relationship between air temperature at 3 feet and soil surface temperature. Extreme temperatures near the soil surface were plotted over extremes occurring on the same day for air-3-feet at the open thermograph station. A linear relationship was indicated within the range of temperatures encountered. Regression lines were then calculated using the empirical formula for a straight line, $Y = a + bx$, where: Y = temperature of the near-soil surface level, and x = temperature of air at 3 feet above the soil surface. The regression lines are shown in figs. 10a-d, and their respective standard errors of estimate and correlation coefficients in table 6.

The standard errors of estimate were rather large for the soil surface regression lines (table 6). This was attributed principally to the large thermometer bulbs which occupied a vertical distance of 12 mm in the highly variable zone near the soil surface. It is felt, however, that the analysis is precise enough to allow a comparison between the two seedbed types, and to permit reasonably reliable predictions of soil surface temperatures for a given temperature at air-3-feet.

Fig. 10a shows that surface temperatures higher than 120° F. can be anticipated on undisturbed soil surfaces when air-3 feet reaches 80°. Surface temperatures as high as 133° may occur when air temperatures reach 85°. Climatological records indicate that extremes greater than 85° are rarely encountered in the coastal areas of Southeast Alaska. Although temperatures in the generally accepted lethal range of +123° were recorded on the undisturbed soil surface, it does not appear likely that they persist for more than a very short period of time or are repeated on successive days.

Table 6.--Standard errors of estimate and correlation coefficients for linear regression lines shown in fig. 10

Seedbed	Recording level	Max. Temp. Standard error of estimate	Max. Temp. Correlation coefficient	Min. Temp. Standard error of estimate	Min. Temp. Correlation coefficient
		(°F)	(r)	(°F)	(r)
Mixed	Air 1-in.	4.36	0.94	2.96	0.85
	Surface	6.93	0.83	3.26	0.84
	Soil 1-in.	4.07	0.87	2.31	0.88
Undisturbed	Air 1-in.	6.93	0.90	3.82	0.79
	Surface	9.69	0.85	4.38	0.78
	Soil 1-in.	2.80	0.86	2.26	0.81

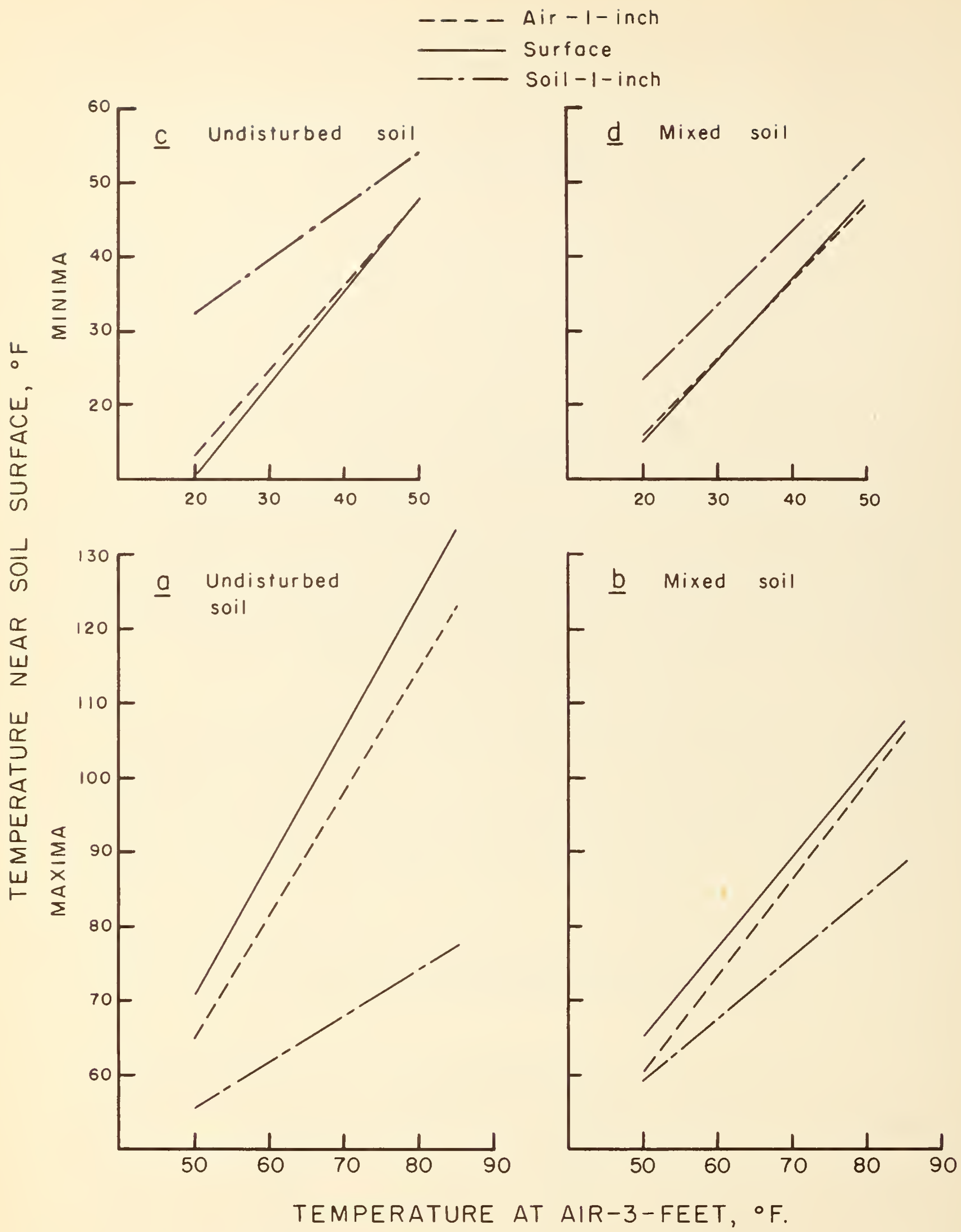

Figure 10.--Regression lines showing relationship between air-3 feet and near-soil-surface levels for maximum and minimum temperatures.

It is very unlikely that mixed soil surfaces reach temperatures at which damage to seedlings occurs. As shown in fig. 10b, this would require an air temperature of about 90°, an extremely high maximum for this region.

Regression lines for the minimum temperature extremes in figs. 10c and 10d show that values of 32°, at or just above both mixed and undisturbed soil surfaces, may be anticipated when nocturnal air minima drop to about 36° to 38°. As mentioned previously, freezing temperatures were observed as late as July on undisturbed surfaces in exposed areas.

Effect of Seedbed on Germination

The mixed and undisturbed seedbeds in the open, and the undisturbed seedbeds in the timber were sown with seed on May 31, 1955. Four hundred seed each of western hemlock, Sitka spruce, and western redcedar were sown on each seedbed type. It is unlikely that the plots received more than an insignificant number of natural seed since the 1954 seed crop in the old-growth stands of Maybeso Valley was very poor.

Cumulative germination is expressed by the curves in fig. 11. The quantity of germinants for all seedbeds is quite low considering that 1200 seed were sown on each seedbed type. At the end of September the cumulative number of seedlings totaled only 136 on the mixed, 62 on the timbered, and 21 on the open undisturbed plots. The reason for the small number of germinants is not known. Trapping indicated that the rodent population was quite high and it is suspected that this was an important factor. Poor viability may have been partly responsible; viability tests were not made on the seed which was collected in a 40-year-old second-growth stand the previous fall. Differences in germination between seedbeds shown in fig. 11 are not influenced directly by seed quality, however, and this factor is therefore of minor importance.

The largest number of seedlings germinated on the open mixed plots and the smallest number on the open undisturbed plots. Germination occurred earlier on the mixed plots and the rate of germination was faster.

The beginning of germination on the mixed plots coincides with the exceptionally warm period between June 18 and 24. A comparatively rapid rate was maintained to the middle of July after which germination began to decrease. A slight acceleration was witnessed in early September following a short, unusually warm period.

Germination began on the open undisturbed plots the second week in July when temperatures were comparatively low and a small amount of precipitation occurred. A warm period followed and germination ceased until cooler temperatures and frequent precipitation again prevailed. Most of the germinants on the undisturbed seedbed appeared during the cool, wet month of August.

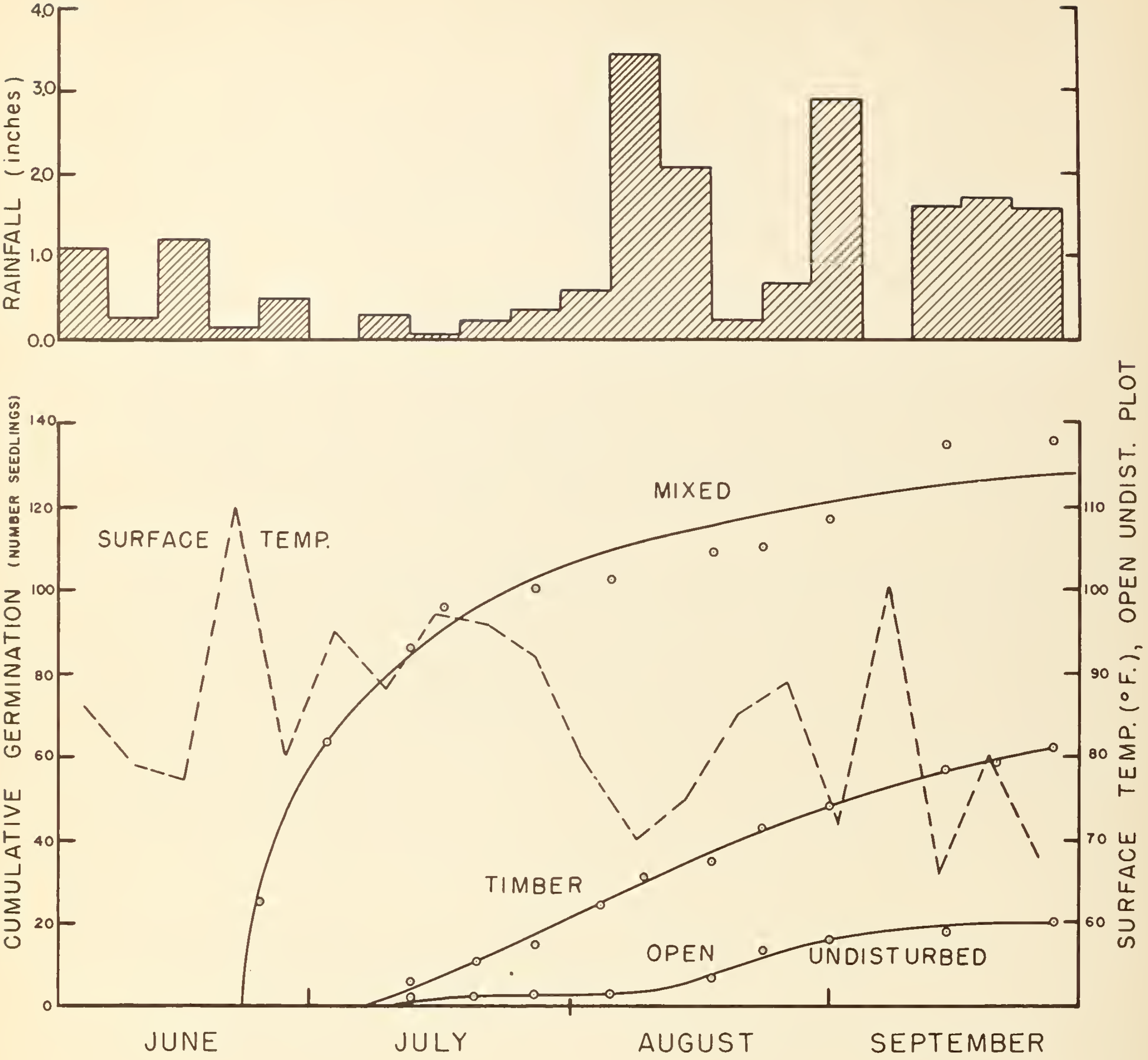

Figure 11.--Cumulative germination curves (all species combined) for the three seedbed types relative to 6-day rainfall and mean maximum surface temperature for the open undisturbed plot.

In the timber, where a cool and moist environment persisted, germination was delayed until the second week in July. A steady, nonfluctuating rate of germination followed throughout the period of record which is due, most likely, to the stable condition of this environment.

Mortality on the mixed plots was 8 percent; on the open undisturbed plots, 24 percent; and in the timber, 19 percent. It was well distributed throughout the period of germination for the mixed seedbed and undisturbed seedbed in the timber. On the open undisturbed plots mortality was confined entirely to the warm periods during the latter part of August and early September. No seedling injury or mortality due to heat lesions was noted on any of the plots.

Poor germination and survival on the open undisturbed seedbeds is not surprising. High temperatures at, and just above, the soil surface result in poor moisture relationships and consequent seedling mortality due to dessication (Godman, 1953). Despite the dry condition of the moss-covered surface, the organic soil immediately below the surface was moist at all times and displayed comparatively cool daytime temperatures. Survival is greatly enhanced if seedling roots become established in this moist organic layer.

Percentage of total germinants by species is presented in table 7. Spruce maintained high relative abundance on all seedbeds. Cedar did best on the mixed seedbed, was almost as abundant in the timber, and greatly reduced on the open undisturbed plots which suggests the importance of adequate moisture for this species. Hemlock germination was very low on all plots which seems to indicate poor viability of the seed. Percentage mortality was evenly distributed among all species on all seedbeds.

Table 7.--Percent of total germinants by species

Seedbed	Total number germinants	Percent of total germinants		
		Western hemlock	Western redcedar	Sitka spruce
Open, mixed	136	9	46	45
Timber, undist.	62	8	32	60
Open, undisturbed	21	5	9	86

At the time of the last 1955 observation on September 27 it was noted that seedlings on the timbered plots were much less advanced than those in the open. Seedlings in the timber had very tender stems which appeared etiolated, and leaves, other than the cotyledons, had not developed. In the open most of the seedlings, regardless of seedbed, displayed hardened stems and abundant leaves.

Damage to seedlings due to sub-freezing temperatures was not observed. Germinants were not prevalent when temperatures less than 32° occurred except in the open on undisturbed plots in September. In the latter instance the seedlings were probably sufficiently hardened to withstand freezing temperatures.

Preliminary observations indicate that winter mortality due to frost heaving may be severe during some years on moist mineral soil seedbeds. Attention will be given to winter mortality on various seedbed types in recently initiated studies.

SUMMARY AND CONCLUSIONS

Air and soil temperature are believed to be important factors influencing germination, survival, and growth of forest trees in Southeast Alaska. Low temperatures such as those encountered beneath old-growth stands are not far above that point at which arresting of plant growth and soil biological activity occur. It is felt that an increase in air and soil temperatures, even of a small magnitude, will be directly beneficial, and perhaps essential, to the satisfactory establishment of reproduction. In accordance with this assumption a study, designed to evaluate the effect of clearcutting on soil and air temperatures, was conducted on an area typical of the coastal islands of this region. Additional observations were made on the range of temperatures encountered on two important seedbed types in clearcut areas in relation to seedling germination and survival.

Air and soil temperatures were found to be considerably increased during late spring and summer periods as a result of clearcutting. The most noticeable increase, as indicated by continuous records of temperatures at air-3-feet and soil-3-inches, was in soil maxima. Next in order of magnitude were air maxima. Air and soil minima were least affected. Maximum temperature differences between open and timber, displayed by 6-day means, ranged from a low of 0.9° F. to a high of 3.0° F. at air-3-feet, and 1.7° to 8.3° at soil-3-inches. The largest daily difference was 17° for soil and 12° for air.

Open soils warmed earlier and cooled sooner and more rapidly than timbered soils. Differences were most pronounced during early season warming and periods of highest air maxima. Clearcutting affected soil temperatures in the deeper soil layers. At a depth of 24 inches differences as great as 5° F. occurred between open and timber. At the 24-inch depth temperatures were quite low and never exceeded 52° in the open and 46° in the timber during the summer of 1955.

Maxima greater than 100° F. were frequently encountered on moss-covered soil surfaces in the open. The highest observed was 130° when air at 3 feet in the open was 84°. By means of regression analyses it was shown that temperatures higher than 120° can be anticipated on undisturbed surfaces when air temperatures reach 80°; surface temperatures may reach 133° when air reaches 85°. Climatological records indicate that extremes higher than 85° are rarely encountered in Southeast Alaska. On mineral soil surfaces maxima higher than 100° were infrequent.

Minima of 32° on both moss and mineral soil surfaces result when air minima drop to about 36°. Freezing temperatures were observed as late as July on undisturbed soil surfaces. Air minima in the thirties are common some years through the first half of June in the open, but nocturnal freezing temperatures did not occur at air-3-feet during the period of record.

Damage to seedlings in the succulent stage is conceivable with the occurrence of either high daytime or low nocturnal temperatures, but it appears that neither occur frequently enough to be of much concern in this region. Seedling injury due to excessive heat or frost was not observed in the present study.

Moss-covered seedbeds proved to be less desirable than mixed soils for germination and early survival. High temperatures probably seriously depleted available moisture, resulting in reduced germination and dessication of seedlings suspended in the moss. Once seedling roots became established in the moist layers below the moss, however, their chance for survival appeared good.

In comparison, seedling germination on mixed soils in the open occurred earlier, the period of germination was more concentrated, and survival was better than on moss-covered seedbeds. Temperatures on mixed soils were not severe and moisture relationships appeared favorable.

Cool temperatures in the timber resulted in late and prolonged germination. Seedlings which germinated on the timbered plots were still in the succulent stage at the end of the growing season.

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